122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Paper ID #11399

What's Standard? Industry Application versus University Education of Engineering Standards

Chelsea Leachman, Washington State University

Chelsea Leachman is the engineering librarian at Washington State University. She obtained here Masters of Library and Information Science from the University of Wisconsin-Milwaukee in 2011. She has a background in science and engineering. She received her Bachelor of Science in Environmental Science with a minor in geology from the University of Idaho 2007.

Prof. Charles Pezeshki, Washington State University

Charles (Chuck) Pezeshki is the Director of the Industrial Design Clinic in the School of MME at Washington State University. The Industrial Design Clinic is the primary capstone vehicle for the School and focuses on industrially sponsored projects with hard deliverables that students must complete for graduation.

What's Standard? Industry Application versus University Education of Engineering Standards

ABET requires engineering students use design standards produced by professional societies during their senior year to prepare for life after graduation. However, no standard approach for educational content development on the use of standards is available and an information deficit exists on how application of these standards differs between industry and academia. To address this need, the first part of our analysis focuses on the use of standards in a capstone mechanical engineering senior design course, a class that is ubiquitous in engineering programs in the United States. The capstone senior design course partners with industry sponsors to produce a product for implementation at the end of a sixteen week semester. An early stage in the design process is the identification of standards applicable to the project. Students are given instruction on finding and locating standards at the library and also through outside sources. Students are asked to seek out standards "at will" rather than being required by the project narrative and record the standards utilized in the final design report. The second part of our analysis surveys the use and organization of standards by the industry sponsors of the design course irrespective of the sponsored projects. The data collected includes how company sponsors acquire standards, utilization rate, and of particular interest is the organization of standards that are purchased for future use. After identifying synergies between the academic and industrial approaches, we propose a foundation of engineering standards education based in the contextual learning curriculum. Finally, we provided recommendations for engineering standards literacy to reinforce the need for life-long learning skills.

Introduction

An engineer's ability to use the correct engineering standards and codes effectively "…can reduce manufacturing costs, create customer satisfaction, open new markets and vastly improve the quality of products and services" [1]. To prepare students for professional practice university engineering programs are responsible, as specified by ABET, to create "…a major design experienced based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints"[2]. Furthermore, standards and technical reports were ranked as the most important types of information by corporate engineers in a survey by Waters, Kauto, and McNaughton [3]. Despite this critical role, little research is available on increasing use of standards literacy or how these skills are transferred to industry once the students graduate.

Ward[4] showed that within corporate firms engineers are obtaining information through a combination of in house databases, personal connections, and corporate library resources. Moreover, Rodrigues[5] discovered that the general corporate expectation is that new engineers be able to locate and manage information sources independently. No study to date has looked in detail at the acquisition and organization of standards within corporate engineering firms.

Despite the documented corporate ranking, academic engineering faculty consider scholarly journal articles as the most important information form[6]. This ranking guided traditional library instruction to focus on journal database subscriptions that students typically do not have access to after graduation. Although the skills of literature searching are transferable to databases and

general search engines, students should not only be able to find the information but be able to apply information to effectively accomplish a specific purpose[7].

Standards and codes incorporation in course work is usually marketed to course instructors by individual associations. For example, in 2013 ASTM released the Professor's Tool Kit to "…help university professors provide information about technical standards as part of their engineering and business curricula"[8]. Another approach to engineering standards education is through online modules created by standards organizations such as the American National Standards Institute (ANSI).

Building on prior library instruction focused on literature searching, standards and codes instruction was targeted to the senior capstone course. When developing standard and codes library instruction the librarian was unfamiliar with the breadth of content required by the students. Napp states that it is "…for librarians and teaching faculty to help students learn how they can locate information using the limited tools they will likely have available on the job"[9]. Additionally one way for students to become independent and highly competent at finding information using limited resources is by integration into the engineering curriculum[9].

In collaboration with the course instructor this study was initiated with the goals of understanding the (1) use of standards by students during the design process and (2) acquisition and organization of standards and codes within corporate engineering firms. The end result being a foundational guide for library instruction of engineering standards literacy.

Student Standard Use

Prior to their final year of coursework, engineering students have little to no knowledge of engineering standards. The students typically have limited knowledge of standards acquired through internships outside of their coursework. During their final year, engineering standards are presented as standalone lecture in their senior capstone design course. Students prior or during the same semester are presented with database and library resources for completing literature reviews in a parallel course.

The presentation of engineering standards is given just prior to project assignment. The timing of the instruction prior to the project assignments is because the first step after project assignment is to complete a codes and standards worksheet (Appendix A) and realistic constraints worksheet (Appendix B). After completing the worksheets the industry sponsors sign off on the scope of the project and standards utilized.

Library instruction introduces students to the history, acquisition and scope regarding standards and codes. Identification of standards and codes is overviewed during the beginning of the design process during the identification of realistic constraints. The instruction of standards and codes includes the subscriptions held through the library in addition to introducing the concept of third party standard vendors. Standards not accessible through already purchased materials are purchased using the senior capstone design course funds.

The completed codes and standards worksheet all include a minimum of two standards. Teams are asked not only about the application of standards but why the standard is being used. Every worksheet included a standard about the safety procedures. One example of a team's understanding of the ramifications for using a standard is the use of ISO 13855: Safety of Machinery and the students reiterate the use of the standard in their project is to prevent a person or part reaching a hazard zone. Testing methods were the second highest used type of standard.

Finally, teams were tasked with completing the discussion and application section of the worksheet. Discussion and application sections included detailed description of the project goals and the implementation of the standards within the design process.

Industry Standards Survey Responses

To gain insight into industries use of standards the course instructor contacted industry sponsors to complete a survey regarding engineering standards, Appendix C. Prior to sending surveys and during the development of this research was found to be exempt from the need for IRB review by the Office of Research Assurances. The survey was completed by nine respondents. While nine responses is by no means considered comprehensive nor representative of the extent of industry standards use, the industry responses were viable due to interest in helping and the relationship with university capstone course and instructor.

Demographics of survey respondents were 100% male with 44% between the ages 30-39, 22% between the ages of 40-49, and 33% over the age of 50. Industry type include 67% private and 33% government (Federal, State, City, etc.). To gain insight into how standards are acquired for a project the respondents were asked to identify the identification process, Table 1.

Table 1: Identification Process of standards for a project

Defined by client requirements of internal management company wide requirements.
Normal and customary standards from our industry, plus customer requirements.
Statement of work (contract), specifications, and state requirements (e.g. IBC)
Each subteam lead is responsible for standards that apply to their area. For example, the ME team designing a metal case part will refer to the appropriate ASTM spec for the alloys considered. EE will refer to the appropriate IEE, JEDEC and IEC specs applicable for their system. The only areas where there is a global requirement is in the case of compliance. The compliance team lead will then dictate the appropriate agency standards for certification of the entire product (CE, FCC, RoHS, UL, etc.)
Corporate standards are used for the design of process equipment and units. Corporate standards are typically based on industry standards, such as API, ASME, IEEE, etc.
I don't worry about any standards. I've always worked on consumer products. We just worry about regulatory approvals such as UL, FCC, and CE.
Business and contractual typically related to safety. Are there nuclear issues, then PAAA. Radioactive sources win work environment, then 10 CRF 835.
The Basis of Design is a front end loaded document created during the Define state of a project. Its completion includes industry and company standards required to complete the basis of design. The BoD is part of the Issue of Design package submitted to the contractor for its basis to complete the project's design.

Industry specific standard are purchased for projects or specified by our clients.

Since there is a broad scope of standards and codes available for engineers to use, industry sponsors were asked if there are certain standards that all engineers should be familiar with. The responses are provided in Table 2.

Table 2: Standards engineers should be familiar with

All mechanical engineers should be aware of broad categories of standards, such as ASME Boiler Code, the Uniform Plumbing Code, etc. But I don't think they need to be "familiar" with them; "aware" is enough. Becoming "familiar" with the relevant standards is one of those things every engineer has to learn once they start their career. They'll always have to learn new things on the job. This is one of them.
International Building Code (IBC) is primary for ME's and CE's. In the back of the IBC there is a "Referenced Standards" it lists other required standards such as: ACI for concrete, AISC for steel structures, ANSI for misc, ASCE for wind and seismic loads, ASME for piping, ASTM for materials, NFPA 70 (NEC) for electrical.
It depends on discipline. An example would be ME that are responsible for pressure vessels and piping would need to be familiar with ASME, API and company standards. ME assigned to rotating equipment would need to be familiar with different standards within API, ASME, etc. EE's and CE's have similar standards.
Each specialty group should be familiar with the applicable standards. ME design should be familiar with ASTM, for example. Also as example, SMT manufacturing and PCB design need to be familiar with IPC standards.
Yes, in the Oil and Gas industry; ASME Sect VIII, div I and Div II, ASME B31/3 refinery piping, ASME B31.4 transportation pipelines liquid ASME B31.8 transportation pipelines gas ANSI 16.5 piping component pressure vs temperature ratings IBC - international building codes ASCE AISC NFPA ISA 84 Safety instrumented systems DOT - interstate pipelines API 650 Above ground storage tanks API 653 main of above storage tanks API 941 NEC
General safety. Specifics have to do with field of work and PE license.
Mechanical and civil engineers working with equipment or structural design should be familiar with AWS welding standards. Engineers working with pressure systems, boilers, or nuclear equipment should be familiar with the ASME Boiler and Pressure Vessel Code. Most other standards we contact internal company experts to get guidance (for example OSHA standards on scaffolding, hoisting and rigging, etc.).
I do not have a standard that comes to mind for all disciplines

While in academia students and faculty are able to access standards though database subscriptions or request for purchase, industry sponsors were asked to identify the method of standard acquisition, Table 3. The indication of other included access through industry specific (i.e. American Society of Mechanical Engineers) and IPC store.

Table 3: Acquisition of Standards

IHS Standards Store	4	44%
TechStreet	1	11%
Document Center	1	11%
IEEE Explore Database	1	11%

ASTM Standards Database Online	4	44%
Company Database/Previously Owned	6	67%
Other	5	56%

Furthermore, once standards are purchased the industry sponsors were asked to describe, if any, what organization system was applied to the standards. Of the nine responses only one response indicated that there was no organization for future use. The other eight responses were asked to elaborate on the organization of the standards, Table 4.

Table 4: Elaboration on the organization of standards

Stored digitally on company network.
Subscriptions are managed by corporate tech library.
Document archival and retrieval system (if digital). Also use SharePoint libraries. Hard copies may be wither the company-wide library or in department libraries.
We purchase and download the files electronically to our server and provide access to all engineers. Some that we use frequently (e.g. AISC) we have numerous hard copies as well. We use the AISC a lot because we design a lot of steel structures. Other engineering firms may not.
Physical copies are stored in an onsite technical library. Online copies are through IHS access.
Our company has an agreement with IHS and standards can be access on line with this agreement. We also have an online database, where company standards can accessed.
Digital version that are stored on our SharePoint site for all engineers to reference.
Hard copies are updated with updates, that was the past, now access to websites is required for updates. The problem is hard copies get used and can/do miss updates.

To understand the historical context of standard use industry sponsors were asked to reflect their perceptions of how standards have changed throughout their career, Table 5.

Table 5: Change of standard use through career

I just manage project design engineers or SMEs work with codes on projects I manage.
Yes. Due mostly to project requirements. I've been working on larger projects with a much more rigorous QA program.
Yes. The state requires new codes and standards be implemented 1 year after the new IBC comes out. Methods of analysis use to be crude in modern times. They were designed to be solved using a slide rule. Most standards have been updated to allow FEA and other more sophisticated computational models, but they still lag behind. Additionally, materials and manufacturing processes are better than in the past and the standards have been revised to accommodate. While this sounds good, they have maintained the "old" and add the "new". The code books are getting longer and longer and it takes more time to navigate through the how to "comply".
The number of standards and use of standards has increased over my career. This could be for many reasons but possibly because of the complexity of the solutions that we provide require us to utilize these more and more.
Standards have always been the basis for the designs we incorporate, so that hasn't changed. The one thing that has been a little complicated is through corporate mergers, utilizing

common corporate standards has been difficult.
No. Consumer electronics has always been rather regimented in terms of standards and certification (over the past 20 years anyway)
Yes, they act as a transfer of intellectual knowledge. Company and API standards act as the learning tool within a company and within an industry. Knowledge does not walk out the door at retirement! Industries cannot afford repeating failures, it is a core business need to get the design right the first time!! It is a must that company's site tech practices are maintained and connect to industry standards.

Finally, it was optional for industry sponsors to share anything else about the involvement of standards by professionals.

Table 6: Additional Comments regarding the use of standards by professionals

It isn't as important to know everything in a standard as it is to know it is there. Also many standards tell you what you must do, but do not tell you how to do it. Some standards tell you exactly how you must do it.
The investment into standards saves significant design time because established practices are defined and reinvention is not needed.
The ASME Boiler & Pressure Vessel code could probably take 2 semesters on it's own. But a basic intro would be quite helpful. Design requirements are scattered through a huge number of pages based on the conditions which apply to your particular equipment. It really takes a lot of time to understand what factors apply to what situations.
We all take strength of materials as engineers - learn the relationship between stress and strain, pressure and temperature, etc. The industry stds - B31.3 for example define acceptable designs techniques, design quality, design verification via pressure testing. Introduction to stds in engineering schools, where time consuming, would be valuable to the graduate. Process safety via hazard and operation studies identify process hazards, mitigation of the hazard is completed via the layer of protection analysis. These are not standards but industry practices and identified by ISA 84. Pressure safety valve design via API 520 and 521 is a must for Chem E's. Hot hydrogen attack via the Neslon curves and API 941 is another important standard.
I've never done much design work as an ME working at DOE Labs (Sandia/PNNL) over the last 11 years. Never needed to use my PE stamp, etc.

Pedagogy Implications

Prior to the study emphasis was placed on the identification and retrieval of standards. Influenced from industry responses and student work the curriculum has shifted to emphasize a broader understanding of standards and standardization. When presenting information to students emphasis is put on the understanding of why standards exist, how they are created and potential avenues for finding or locating relevant standards outside of academia.

Students in the course directly work with industry sponsors and are instructed by the faculty member to seek advice from their industry contact regarding the appropriate standard(s) to use for the projects. Industry responses reinforced the method of standard identification by using professional experience and client constraints. Teaching students to use professional contacts

and organization reinforces the survey result that "the investment into standards saves significant design time because established practices are defined and reinvention is not needed."

The survey also strengthened the notion that students need to be familiar with the existence and importance of standards. Importance of standards is presented to the students using industry examples of consumer safety and manufacturing practices. Both current and historical examples are shown to students. The historical context presents students with the realization that standards are created from a collection of professional experience and this was reinforced by the response in the survey that "Company and API standards act as the learning tool within a company and within an industry. Knowledge does not walk out the door at retirement!" Through the importance of standards and historical context transitions the conversation with students to the development of standards.

Survey results showed that standards used in industry are commonly from a collection of previously purchased standards. Students are now advised that while in academia they have resources that might not be available after graduation and to seek out the information from colleagues about existing collection held within a company, if any. While there was mention of print standards students should be familiar with the electronic copies either retrieved from an online database or purchased and downloaded individually due to the indication of survey responses of digital storage. Students accessing standards through online databases is comparative with the practice of digital storage describe in survey results.

Overall, the focus of our engineering standards education has turned to the comprehension of the standard during a project rather than the focus on identification. This allows students to gain experience with the application of a standard to a project with mentorship from the faculty member.

Conclusion

Understanding student and industry use of standards allows engineering educators to fulfill the university's mission by creating responsible leaders who are able to serve society. Overall, engineering standards instruction must give students the confidence to transition information skills from academia to professional. To increase students' confidence they should be able to practice collaboration and engineering standard use within academia.

References

[1] Batik, A., *The Engineering Standard A Most Useful Tool*, Ashland, Ohio: BookMaster/El Rancho, 1992.

[2] Engineering Technology Accreditation Commision," Criteria for accrediting engineering programs", *ABET Report E001 11/7/14*, 2014.

[3] Waters, N., E. Kasuto, and F. McNaughton," Partnership between engineering libraries: Identifying information literacy skills for a successful transition from student to professional", *Science and Technology Libraries* Vol. 31, No. 1, 2012, pp. 124-132.
[4] Ward, M.," A survey of engineers in their information world", *Journal of Librarianship and Information Science* Vol. 33, No. 4, 2001, pp. 168-176.
[5] Rodrigues, R.J.," Industry Expectations of the New Engineer", *Science & Technology Libraries* Vol. 19, No. 3/4, 2001, pp. 179-188.
[6] Robbins, S., D. Engel, and C. Kulp," How unique are our users? Comparing responses regarding the information-seeking habits of engineering faculty", *College & Research Libraries* Vol. 72, No. 6, 2011, pp. 515-532.
[7] Association of College and Research Libraries., "Information Literacy Competency Standards for Higher Education", Chicago, Illinois: American Library Association, 2000.
[8] Olshefsky, J., "ASTM debuts professor's tool kit: New ASTM resource provides materials for standards education", *Standardization News*, 2013, pp. 18.
[9] Napp, J.B.," Survey of library services at Engineering News Record's top 500 design firms: Implications for engineering education", *Journal of Engineering Education* Vol. 93, No. 3, 2004, pp. 247-252.

Appendix A

ME416 Codes and Standards Worksheet

Group Name _____

Project _____

Purpose/major need of Project:

Major Divisions of Project (Functional, Energy Paradigm, Structural)

Applicable Codes and Standards (and why)

Discussion and Application (take up as many pages as necessary)

Attach e-mail approval of Project Sponsor

Appendix B

ME416 Realistic Constraints Worksheet – to be reviewed during Mid-Term Design Review

Group Name _____

Project _____

Purpose/major need of Project:

Major Divisions of Project (Functional, Energy Paradigm, Structural)

Economic Constraints:

Environmental Constraints:

Social Constraints:

Political Constraints:

Ethical Constraints:

Safety Constraints:

Manufacturability:

Sustainability:

Discussion and Application (take up as many pages as necessary)

Attach e-mail approval of Project Sponsor

Appendix C

Industry Standards Use Survey

Information Sheet

Thank you for participating in this Survey of Engineering Standards Use. The purpose of this survey is to collect information from engineering professionals involving the access of engineering standards, utilization rate, and the organization of standards that are purchased for future use. Data collected will provided recommendations for engineering standards literacy.

RISKS AND BENEFITS
There are no risks beyond those encountered in daily life, though participants can identify or disclose information that will cause them to be identified. The benefit of participating in the survey is the satisfaction of knowing that the information shared will assist classroom instruction methods.

CONFIDENTIALITY PROTECTIONS
Individual responses to the surveys will be retained indefinitely by the primary investigator. Any results shared (e.g., publication via a conference paper) will be aggregated and anonymous. Information about you will be kept confidential to the extent permitted or required by law.

RIGHT TO DECLINE OR WITHDRAW AT ANY TIME
Participation is this research study is voluntary and you have the right to decline or withdraw from the survey at any time without penalty. If you have questions regarding the study or the rights of participants, please contact Chelsea Leachman (chelsea.leachman@wsu.edu), Principal Investigator. For questions about your rights as a research participant; or if you have questions, complaints, or concerns about the research, you may call the WSU Institutional Review Board at (509)335-9661.

Thank you again. By clicking "Agree" you are acknowledging the potential risks above.

Gender
- Male
- Female
- Choose not to identify

Age Group
- 20-24
- 25-29
- 30-39
- 40-49
- 50+

Industry Type

- Private
- Government (Federal, State, City, etc.)
- Education
- Self Employed
- Other: _____

Can you describe the identification process of standards for a project?

- Example: defined by project description, engineers independently identify standards, etc.

Are there certain standards all engineers should be familiar with?

How are standards acquired?
Choose all that apply

- IHS Standards Store
- TechStreet
- Document Center
- IEEE Explore Database
- ASTM Standards Database (online)
- Company Database/Previously Owned
- Other:_____

Once standards are purchased, are they organized for future use?
Example: organized through online purchasing company, phyical location within company, etc.

Has the use of standards changed throughout your career? If so, why?

Is there anything else you would like to add about the use of standards by professionals?